26022_S24, August 2024

1)

Hvilket grundstofpar har det samme antal valenselektroner i grundtilstanden?

Which pair of elements has the same number of valence electrons in the ground state?

Ingen af mulighederne / *None of the options* *
Karbon og Magnesium / *Carbon and Magnesium*
Karbon og Bor / *Carbon and Boron*
Karbon og Aluminium / *Carbon and Aluminium*
Karbon og Krom / *Carbon and Chromium*

Suggested solution:

See example 7.11 in the course book (Chang / Goldsby)

2)

Arranger grundstofferne i gruppe 1 i det periodiske system i rækkefølgen af stigende polariserbarhed:

Arrange the elements in group 1 of the periodic table in the order of increasing polarizability:

Li < Na < K < Rb < Cs*
Cs < Rb < K < Na < Li
Li < Cs < Na < K < Rb
Na < Li < Cs < Rb < K
Ne < F < O < N < C < B < Be < Li

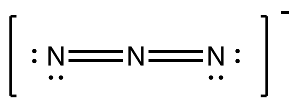
<u>Suggested solution:</u>

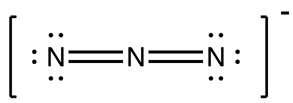
A groups is a vertical arrangement, i.e. column, of elements in the periodic table.
Polarizability increases with atomic radius when electrons are further from the nucleus, and atomic radius increases when we go down in a group. Thus Li < Na < K < Rb < Cs

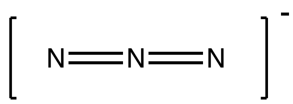
3)

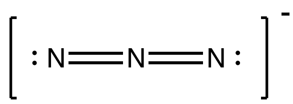
Hvilken af de følgende illustrationer repræsenterer en korrekt Lewis-struktur for azid-anionen (N_3^-)?

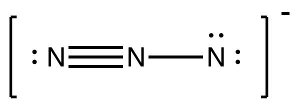
Which of the following illustrations represents a valid Lewis structure for the azide anion (N_3^-)?

 *









Suggested solution:

See Section 9.6-9.7 in the course book (Chang / Goldsby)

4)

Tetrafluoroborat-anionen (BF_4^-) dannes gennem reaktionen mellem bortrifluorid (BF_3) og et fluoridsalt. Hvilken geometrisk form kan forventes for tetrafluorboratanionen (BF_4^-)?

The tetrafluoroborate anion (BF_4^-) is formed through the reaction between boron trifluoride (BF_3) and a fluoride salt. Which geometric shape can be expected for the tetrafluoroborate anion (BF_4^-)?

Tetraedrisk / *Tetrahedral**
Trigonal plan / *Trigonal planar*
Lineær / *Linear*
Plankvadratisk / *Square planar*
Forvrænget tetraedrisk / *Distorted tetrahedral*

Suggested solution:

See Section 10.1 in the course book (Chang / Goldsby)

AB_4 according to the VSEPR model (four bonding pairs). 8 valence electrons which form 4 electron pairs. Thus tetrahedral geometry.

5)

Det alifatiske kulbrinte C_6H_{14} har 5 isomerer. Hvilken af dem kan forventes at have det højeste kogepunkt?

The aliphatic hydrocarbon C_6H_{14} has 5 isomeric forms. Which of them can be expected to have the highest boiling point?

Hexan / *Hexane* *
2,2-Dimethylbutan / *2,2-Dimethylbutane*
3-Methylpentan / *3-Methylpentane*
2-Methylpentan / *2-Methylpentane*
2,2-Dimethylbutan / *2,2-Dimethylbutane*

Suggested solution:

Dispersion forces are surface area dependent – the least branched chain has larger surface area – thus hexane

(note that two of the answer options are identical – i.e. 4 unique answer options)

6)

15,0 g jern(III)chlorid hexahydrat ($FeCl_3 \cdot 6H_2O$) opløses i 200 mL vand. Hvad er opløsningens kogepunkt ved 1 atm., givet at densiteten, K_b og normalt kogepunkt for vand er henholdsvis 1,00 g/cm^3, 0,52 °C/m og 100,0 °C. Antag, at van´t Hoff-faktoren for $FeCl_3$ er 3,4, og at krystalvandet frigives ved opløsning.

15.0 g of iron(III) chloride hexahydrate ($FeCl_3 \cdot 6H_2O$) is dissolved in 200 mL of water. What is the boiling point of the solution at 1 atm., given that the density, K_b and normal boiling point for water is 1.00 g/cm^3, 0.52 °C/m, and 100.0 °C, respectively. Assume that the van´t Hoff factor for $FeCl_3$ is 3.4 and that the crystal water is released upon dissolution.

100,5 °C *
100,9 °C
100,1 °C
99,4 °C
101,9 °C

Suggested solution:

n ($FeCl_3 \cdot 6H_2O$) = (15.0 g) / (270.2 g/mol) = 0.0555 mol

n(H2O, from salt) = 0.3330 mol

m(H2O, from salt) = 0.3330 mol * 18.02 g/mol = 6.000 g

m(H2O, total) = 206 g

molality ($FeCl_3$) = 0.05550 mol / 0.206 kg = 0.2694 mol/kg

$\Delta T = i \times K_b \times m = 3.4 \times 0.52$ °C/m $\times 0.2694$ m = 0.476 °C

$T_b = T_b^0 + \Delta T$ = 100.0 °C + 0.48 °C = 100.5 °C

7)

Bly (Pb) krystalliserer i kubisk fladecentreret (fcc) gitterstruktur med en densitet på 11,34 g/cm^3. Hvor mange enhedsceller er der i en blykugle med en diameter på 1,0 cm?

Lead (Pb) crystallizes in face-centered cubic (fcc) lattice structure with a density of 11.34 g/cm^3. How many unit cells are present in a ball (sphere) of lead with a diameter of 1.0 cm?

$4{,}3 \times 10^{21}$ *
$4{,}2 \times 10^{22}$
$1{,}8 \times 10^{21}$
$9{,}1 \times 10^{23}$
$2{,}7 \times 10^{21}$

Suggested solution:
V(Pb) = 0.5236 cm^3
m(Pb) = 5.9376 g
n(Pb) = 5.9376 g / (207.2 g/mol) = 0.02865 mol
1 mol = 6.022×10^{23} atoms
Number of Pb atoms = 0.02865 mol × 6.022×10^{23} atoms / mol = 1.7257×10^{22} atoms

fcc structure implies 4 atoms per unit cell

Total number of unit cells = Number of Pb atoms / Number of atoms per unit cell
$1.7257 \times 10^{22} / 4 = 4.31 \times 10^{21}$

8)

Hastighedskonstanten for en reaktion er blevet bestemt til 4,0 × 10^{-3} s^{-1}. Hvad er temperaturen, givet at Arrhenius-konstanten er 8,4 × 10^{13} s^{-1} og at aktiveringsenergien er 100 kJ mol^{-1}?

The rate constant for a reaction has been determined to 4.0 × 10^{-3} s^{-1}. What is the temperature, given that the Arrhenius constant is 8.4 × 10^{13} s^{-1} and that the activation energy is 100 kJ mol^{-1}?

47 °C*
13 °C
25 °C
32 °C
39 °C

<u>Suggested solution:</u>

Arrhenius equation (in logarithmic form)
$\ln(k) = \ln(A) – E_a/RT$
$\ln(k) = \ln(A) – (1/T) \times (E_a/R)$

$T = E_a / (R \times (\ln(A)-\ln(k))$

$T = E_a / (R \times (\ln(A)-\ln(k))$

$T = 100000 / (8.314 \times (\ln(8.4 \times 10^{13})-\ln(4.0 \times 10^{-3})) = 320.0$ K

320 K = 47 °C

9)

I en kolbe med en gasformig ligevægtsblanding af brint, nitrogen og ammoniak er ligevægtskoncentrationerne [H_2] = 0,100 M, [N_2] = 0,040 M, og [NH_3] = 0,003 M. Beregn ligevægtskonstanten, K_c, givet at:

$3H_2$ (g) + N_2 (g) ⇋ $2NH_3$ (g)

In a flask with a gaseous equilibrium mixture of hydrogen, nitrogen and ammonia, the equilibrium concentrations are [H_2] = 0.100 M, [N_2] = 0.040 M, and [NH_3] = 0.003 M. Calculate the equilibrium constant, K_c, given that:

$3H_2$ (g) + N_2 (g) ⇋ $2NH_3$ (g)

0,225 *
0,750
$3{,}60 \times 10^{-10}$
0,500
$6{,}75 \times 10^{-5}$

Suggested solution:

Balanced reaction:

$3H_2$ (g) + N_2 (g) ⇄ $2NH_3$ (g)

$K = [NH_3]^2 / ([H_2]^3 \times [N_2]) = (0.003)^2 / (0.1^3 \times 0.04) = 0.225$

10)

Tin(IV)iodid dannes ved at reagere tin med jod ifølge reaktionen:

$Sn + 2I_2 \rightarrow SnI_4$

Hvad er det maksimale teoretiske udbytte af SnI_4, der kan opnås fra en blanding af 5,0 g tin og 9,0 g jod?

Tin(IV) iodide is formed by reacting tin with iodine according to the reaction:

$Sn + 2I_2 \rightarrow SnI_4$

What is the maximum theoretical yield of SnI_4 that can be obtained from a mixture 5.0 g of tin and 9.0 g iodine?

11 g *
26 g
14 g
2,1 g
13 g

Suggested solution:

	Sn	I_2	SnI_4
M (g/mol)	118.71	253.8	626.3
m (g)	5.0	9.0	
n(mmol)	42.1	35.5	

Full conversion of Sn requires 84.2 mmol I_2. Hence I_2 is limiting.

Full conversion of I_2 would yield 17.7 mmol SnI_4

$n(SnI_4) = 17.7$ mmol
$m(SnI_4) = 626.3$ g/mol $\times 17.7 \times 10^{-3}$ mol $= 11.1$ g

11)

Vandig opløsning af calciumchlorid tilsættes i overskud til 100 mL vandig flussyre, HF (aq.), hvilket resulterer i udfældning af 1,5 g CaF_2. Hvad var koncentrationen af flussyre før tilsætning af calciumchlorid?

Excess aqueous solution of calcium chloride is added to 100 mL aqueous hydrofluoric acid, HF (aq.) resulting in precipitation of 1.5 g CaF_2. What was the concentration of hydrofluoric acid before the addition of calcium chloride?

0,4 M *
0,2 M
0,1 M
1,0 M
0,8 M

Suggested solution:

Precipitation reaction:

Ca^{2+} (aq.) + $2F^-$ (aq.) $\rightarrow$ CaF_2 (s)

M (CaF_2) = 78.08 g/mol
n (CaF_2) = 1.5 g / 78.08 g/mol = 0.0192 mol

n(HF) = 2n(CaF_2) = 0.0384 mol

C(HF) = n/V = 0.0384 mol / 0.1 L = 0.3842 M

12)

Udstødningsgassen fra en forbrændingsmotor blev boblet gennem en vandig opløsning af bariumhydroxid ved en strømning på 1,0 L/min (25 °C, 1 atm.), hvilket resulterede i udfældning af bariumkarbonat ifølge reaktionen:

$Ba(OH)_2$ (aq.) + CO_2 (g) → $BaCO_3$ (s) + H_2O (l)

4,03 g $BaCO_3$ blev opsamlet efter 10 minutter. Hvad var partialtrykket af CO_2 i udstødningsgassen, hvis man antager fuldstændig omdannelse til $BaCO_3$, og at gassen kan beskrives som en ideal gas?

The exaust gas from a combustion engine was bubbled through an aqueous solution of barium hydroxide at a flow of 1,0 L/min (25 °C, 1 atm.), which resulted in precipitation of barium carbonate according to the reaction:

$Ba(OH)_2$ (aq.) + CO_2 (g) → $BaCO_3$ (s) + H_2O (l)

4.03 g of $BaCO_3$ was collected after 10 minutes. What was the partial pressure of CO_2 in the exhaust gas, assuming complete conversion to $BaCO_3$ and that the gases can be described as an ideal gas?

0,05 atm*
0,10 atm
0,15 atm
0,20 atm
0,25 atm

Suggested solution:

m ($BaCO_3$) = 4.03 g
M($BaCO_3$) = 197.3 g/mol
n ($BaCO_3$) = 0.0204 mol = n(CO_2)

Total volume of CO_2 after 10 min

V (CO_2) = nRT/P = (0.0204 mol × 0.0821 L × atm. K^{-1} mol^{-1} × 298 K) / (1 atm) = 0.5 L

10 L gas in total after 10 min; i.e. 0.5 L CO_2 and 9.5 L "other gases"; i.e. 5 vol.% CO_2

Ideal gasses have the same mole volume. Dalton´s law of partial pressure:

5 vol.% CO_2 → $p(CO_2)$ =0.05 atm (absolute pressure 1 atm)

13)

Nitromethan (CH_3NO_2) er en farveløs væske med en densitet på 1,14 g/mL. Det er hovedkomponenten i "Top Fuel", og brænder i henhold til følgende reaktion:

$4CH_3NO_2$ (l) + $5O_2$ (g) → $4CO_2$ (g) + $6H_2O$ (g) + 4NO (g)

Hvad er det samlede volumen luft (25 °C, 1 atm., ideel gas), der kræves for at forbrænde 100 mL nitromethan, hvis det antages, at partialtrykket af O_2 i luft er 0,2 atm.?

Nitromethane (CH_3NO_3) is a colorless liquid with a density of 1.14 g/mL. It is the main component in "Top Fuel", and burns according to the following reaction:

$4CH_3NO_2$ (l) + $5O_2$ (g) → $4CO_2$ (g) + $6H_2O$ (g) + 4NO (g)

What is the total volume of air (25 °C, 1 atm., ideal gas) required to burn 100 mL nitromethane, assuming that the partial pressure of O_2 in air is 0.2 atm.?

286 L *
16 L
78 L
40 L
110 L

<u>Suggested solution:</u>

M(CH_3NO_2) = 61.04 g/mol
m(CH_3NO_2) = 114 g
n(CH_3NO_2) = 1.8675 mol

n(O_2) = 2.3344 mol

V (O_2) = nRT/P = (2.3344 mol × 0.0821 L × atm. K^{-1} mol^{-1} × 298 K) / (1 atm) = 57.11 L

V (air) = 285.56 L

14)

Beregn standardentalpiændringen for dannelsen af $AlCl_3$ (s) ifølge reaktionen:

$2Al\ (s) + 3Cl_2\ (g) \rightarrow 2AlCl_3\ (s)$

I betragtning af at:

$HCl\ (g) \rightarrow HCl\ (aq)$	$\Delta H^0 = -75$ kJ/mol
$H_2\ (g) + Cl_2\ (g) \rightarrow 2HCl\ (g)$	$\Delta H^0 = -185$ kJ/mol
$AlCl_3\ (aq) \rightarrow AlCl_3\ (s)$	$\Delta H^0 = 323$ kJ/mol
$2Al\ (s) + 6HCl\ (aq) \rightarrow 2AlCl_3\ (aq) + 3H_2\ (g)$	$\Delta H^0 = -1049$ kJ/mol

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Calculate the standard enthalpy change for the formation of $AlCl_3$ (s) according to the reaction:

$2Al\ (s) + 3Cl_2\ (g) \rightarrow 2AlCl_3\ (s)$

Given that:

$HCl\ (g) \rightarrow HCl\ (aq)$	*$\Delta H^0 = -75$ kJ/mol*
$H_2\ (g) + Cl_2\ (g) \rightarrow 2HCl\ (g)$	*$\Delta H^0 = -185$ kJ/mol*
$AlCl_3\ (aq) \rightarrow AlCl_3\ (s)$	*$\Delta H^0 = 323$ kJ/mol*
$2Al\ (s) + 6HCl\ (aq) \rightarrow 2AlCl_3\ (aq) + 3H_2\ (g)$	*$\Delta H^0 = -1049$ kJ/mol*

- $1{,}4 \times 10^3$ kJ/mol *
- $9{,}9 \times 10^2$ kJ/mol
- $3{,}0 \times 10^2$ kJ/mol
- $1{,}6 \times 10^3$ kJ/mol
- $5{,}0 \times 10^2$ kJ/mol

<u>Suggested solution:</u>

$2Al\ (s) + 6HCl\ (aq) \rightarrow 2AlCl_3\ (aq) + 3H_2\ (g)$	$\Delta H^0 = -1049$ kJ/mol
$6HCl\ (g) \rightarrow 6HCl\ (aq)$	$\Delta H^0 = 6(-75)$ kJ/mol
$3H_2\ (g) + 3Cl_2\ (g) \rightarrow 6HCl\ (g)$	$\Delta H^0 = 3(-185)$ kJ/mol
$2AlCl_3\ (aq) \rightarrow 2AlCl_3\ (s)$	$\Delta H^0 = 2(323)$ kJ/mol

Adding these reactions together, we get the reaction of interest:

$2Al\ (s) + 3Cl_2\ (g) \rightarrow 2AlCl_3\ (s)$ $\quad \Delta H^0 = -1408$ kJ/mol

15)

Bestem ligevægtskonstanten ved 25 °C for følgende reaktion:

Sn^{2+} (aq.) + Mn (s) ⇋ Sn (s) + Mn^{2+} (aq.)

Givet at:

Sn^{2+} (aq) + $2e^-$ → Sn (s) E^0 = -0.14 V
Mn^{2+} (aq) + $2e^-$ → Mn (s) E^0 = -1.18 V

Determine the equilibrium constant at 25 °C for the following reaction:

Sn^{2+} (aq.) + Mn (s) ⇋ Sn (s) + Mn^{2+} (aq.)

Given that:

Sn^{2+} (aq) + $2e^-$ → Sn (s) E^0 = - 0.14 V
Mn^{2+} (aq) + $2e^-$ → Mn (s) E^0 = -1.18 V

$1,4 \times 10^{35}$ *
$3,8 \times 10^{17}$
$4,0 \times 10^{-54}$
$4,1 \times 10^{44}$
$2,0 \times 10^{22}$

Suggested solution:

Sn^{2+} (aq) + $2e^-$ → Sn (s) E^0 = -0.14 V
Mn^{2+} (aq) + $2e^-$ → Mn (s) E^0 = -1.18 V

Hypothetical galvanic cell:

Anode (oxidation): Mn (s) → Mn^{2+} (aq) + $2e^-$
Cathode (reduction): Sn^{2+} (aq) + $2e^-$ → Sn (s)

$E^0_{cell} = E^0_{red} – E^0_{ox}$ = -0.14 V - (-1.18) V = 1.04 V

E^0_{cell} = (RT/nF)lnK

E^0_{cell} = (0.0257/2) lnK

ln K = (2 × 1.04 V) / 0.0257 V = 80.93

K = e^80.93 = 1.4×10^{35}

16)

Pyridin er svagt basisk og reagerer med vand i henhold til reaktionen nedenfor. Ved 25 °C er ligevægtskonstanten K_b 1,6 × 10^{-9}. Hvad er pH-værdien af en vandig pyridinopløsning med en koncentration på 100 mM ved 25 °C?

$C_5H_5N + H_2O \leftrightharpoons C_5H_5NH^+ + OH^-$

Pyridine is weakly basic and reacts with water according to the reaction below. At 25 °C, the equilibrium constant K_b is 1.6 × 10^{-9}. What is the pH of an aqueous pyridine solution with a concentration of 100 mM at *25 °C?*

$C_5H_5N + H_2O \leftrightharpoons C_5H_5NH^+ + OH^-$

9,1 *
10,5
6,7
7,5
8,4

Suggested solution:

	$C_5H_5N + H_2O \quad \leftrightharpoons$	$C_5H_5NH^+$ +	OH^-
Initial	0.100	0	0
Change	-x	+x	+x
Eq.	0.100-x	x	x

$K_b = 1.6 \times 10^{-9} = [C_5H_5NH^+][OH^-] / [C_5H_5N]$

Assume x<<0.100 and:

$1.6 \times 10^{-9} = x^2 / (0.100-x) = x^2 / 0.100$
$x^2 = 0.100 \times 1.6 \times 10^{-9}$
$x = 1.265 \times 10^{-5}$ or -1.265×10^{-5} (physically impossible)

Test approximation:
1.265×10^{-5} M / 0.100 M = 0.013% (approx. ok)

At equilibrium:
$[OH^-] = 1.265 \times 10^{-5}$ M
pOH = $-\log 1.265 \times 10^{-5} = 4.898$
pH=14-pOH=9.1

17)

Sølv(I)sulfats opløselighed i vand ved 100 °C er 1,4 g pr. 100 mL. Hvad er den numeriske værdi af opløselighedsproduktet af dette salt ved 100 °C?

The solubility of silver(I) sulfate in water at 100 °C is 1.4 g per 100 mL. What is the numerical value of the solubilty product of this salt at 100 °C?

$3,6 \times 10^{-4}$ *

$4,0 \times 10^{-5}$

$1,4 \times 10^{-5}$

$4,5 \times 10^{-3}$

$1,6 \times 10^{-9}$

Suggested solution:

Ag_2SO_4 (s) ⇋ $2Ag^+$ (aq.) + SO_4^{2-} (aq.)

$M(Ag_2SO_4)$ = 311.87 g/mol

$n(Ag_2SO_4)$ = 1.4 g / 311.87 g/mol = 0.00449 mol

$n(Ag^+)$ = 0.00898 mol

$n(SO_4^{2-})$ = 0.00449 mol

$C(Ag^+)$ = 0.00898 mol / 0.1 L = 0.0898 M

$C(SO_4^{2-})$ = 0.00449 mol / 0.1 L = 0.0449 M

$K_{sp} = [Ag^+]^2 [SO_4^{2-}] = 3.62 \times 10^{-4}$ (M^3)

18)

Angiv hvilket sæt støkiometriske koefficienter (a-f), der balancerer nedenstående redoxreaktion i vandigt surt miljø:

a H^+ (aq) + *b* MnO_4^- (aq) + *c* H_2O_2 (aq) → *d* Mn^{2+} (aq) + *e* O_2 (aq) + *f* H_2O

Indicate which set of stoichiometric coefficients (a-f) that balances the redox reaction below in aqueous acidic environment:

a H^+ (aq) + *b* MnO_4^- (aq) + *c* H_2O_2 (aq) → *d* Mn^{2+} (aq) + *e* O_2 (aq) + *f* H_2O

a = 6, *b* = 2, *c* = 5, *d* = 2, *e* = 5, *f* = 8 *
a = 3, *b* = 1, *c* = 2, *d* = 1, *e* = 3, *f* = 5
a = 12, *b* = 2, *c* = 5, *d* = 2, *e* = 5, *f* = 10
a = 2, *b* = 2, *c* = 1, *d* = 2, *e* = 3, *f* = 5
a = 24, *b* = 4, *c* = 4, *d* = 4, *e* = 16, *f* = 16

Suggested solution:

6 H^+ (aq) + **2** MnO_4^- (aq) + **5** H_2O_2 (aq) → **2** Mn^{2+} (aq) + **5** O_2 (aq) + **8** H_2O

$10e^- + 16H^+ + 2MnO_4^- \rightarrow 2Mn^{2+} + 8H_2O$
$5H_2O_2 \rightarrow 5O_2 + 10H^+ + 10e^-$

19)

Hvilken af følgende komplekser kan kun findes i én geometrisk isomerform?

Which of the following complexes can be found in only one geometrical isomer form?

$[CoCl_4]^{2-}$ (Tetraedrisk / *Tetrahedral*) *
$[Pt(NH_3)_2Cl_2]$ (Plankvadratisk / *Square planar*)
$[Ni(CN)_2Br_2]^{2-}$ (Plankvadratisk / *Square planar*)
$[Co(NH_3)_4Cl_2]^+$ (Oktaedrisk / *Octahedral*)
$[Co(NH_3)_3Cl_3]$ (Oktaedrisk / *Octahedral*)

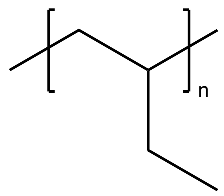
<u>Suggested solution:</u>

$[CoCl_4]^{2-}$ (tetrahedral)

20)

Hvilken monomer blev brugt til at fremstille polymeren med følgende struktur?

Which monomer was used to prepare the polymer with structural repeat unit shown below?



1-Buten / *1-Butene* *
2-Buten / *2-Butene*
1-Penten / *1-Pentene*
2-Penten / *2-Pentene*
Propen / *Propene*

<u>Suggested solution:</u>

1-butene